

**YEAR 2: DEVELOPMENT OF A WEB-BASED SURVEILLANCE AND AUDITING
TOOL (WEBSAT) TO ANALYZE AIRCRAFT MAINTENANCE OPERATIONS**
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The systematic evaluation of data collected on aviation maintenance processes can provide feedback on the performance of an airline and proactively support the decision-making process prior to the dispatch of the aircraft. In order to evaluate data, it is critical that the data being collected is standardized. This can be ensured by collecting data on variables, defined as *process measures*, which adequately measure the aircraft maintenance processes and eliminate existing inconsistencies. Once the data is captured by virtue of the process measures, analysis can be done to identify the problematic areas affecting the safety of an aircraft. This report briefly explains the methodology adopted during Phase I to identify and validate the process measures for the aviation maintenance processes. Phase II elaborates on the product design methodology used to prototype the technical audit module for WebSAT.

PURPOSE AND RATIONALE

It is evident from the literature that maintenance errors have a high impact on the safety of an aircraft. Various methodologies have been adopted in analyzing these errors so as to recommend human factors interventions that enhance the safety of an aircraft. Error classification schemes (Patankar, 2002) are very useful to identify weak points in a system, provided they are backed by comprehensive investigation procedures. In addition to these schemes, empirical models are needed to illustrate how the parts of the system work to influence outcomes. Recent example would be the Maintenance Error Decision Aid (MEDA) (Rankin et al., 2000). MEDA helps analysts identify the contributing factors that lead to an aviation accident. However, MEDA process is dependent on the erring technician's willingness to be interviewed about an error, anything that would decrease this willingness, such as a fear of being punished for the error, would have a detrimental effect on MEDA implementation.

Furthermore, such efforts tend to be reactive in nature, analyzing the accidents subsequent to their occurrence. Hence, there is a need for empirically validated models/tools that capture data on maintenance work and provide a means of assessing this data prior to dispatch of the aircraft. Also, it should be ensured that such models facilitate standardization. In order to contend with this issue, the current research proposes that standardization in data collection can be obtained by collecting data on variables which measure maintenance processes and eliminate existing inconsistencies. These variables are defined by the research team as *process measures*. Process measures incorporate the response and observation-based data collected from various aviation maintenance processes and facilitate the process of data analysis. The current research seeks to collect and present the error causes and occurrences using a web based surveillance and auditing tool (WebSAT) tool (Kapoor et al. 2004) which incorporates these process measures. WebSAT will capture and analyze data for the processes of surveillance, auditing and airworthiness directives control. This report elaborates on the results obtained from the first phase of the project, which is identification and validation of the process measures and also focuses on the preliminary results achieved in the second phase of the project, which is the development of WebSAT prototype.

The WebSAT system will be used by users from the four work functions of surveillance, technical audits, internal audits and airworthiness directives (AD) control as mentioned before. Within each work function there are two types of users – one at the operator level (e.g., auditors) who collects the data for various maintenance processes and the other being the managers of the different work functions of the quality assurance department of an airline who are more interested in the analysis of the data gathered. The upper management is also another potential user who uses the tool to administer the overall adequacy of all the processes.

With the introduction of process measures, the auditors or other personnel who are responsible for data collection will now be also responsible to categorizing the data obtained from a work card, or a checklist into respective process measure. Given the different scenarios that are to be presented to each user, based on their requirements, the design of the system plays a vital role in the accomplishment of the users' goals. Every design decision plays a role in the overall utility of the system in achieving the primary goal of ensuring aircraft safety. Since there are totally four modules to design, the WebSAT team has tried to familiarize itself with all the typical scenarios and decisions that a user makes in their daily work routine. This report further discusses about the implementation of design for the Technical Audit (TA) Module of WebSAT.

METHODOLOGY – PHASE I

Process Measures Identification and Validation

The team gained a comprehensive view of surveillance, auditing and airworthiness directives work functions during data gathering sessions. The data collection methodology employed has a direct effect on the quality and value of the information collected. The team adopted interviews focus groups, and observation sessions as these allowed them to take a first-hand look at the stakeholders' work environments and collect relevant procedural documents (Iyengar et al. 2004). Table 1 below shows two types of users who were interviewed during data gathering sessions. The first were employees in managerial positions, who would be involved with data analysis and would use findings, and other information from their respective work domain to keep a vigil on the performance of their work division. The second group

of users was quality assurance (QA) representatives or auditor personnel from the various work functions, who collect and enter maintenance data on a daily or a periodic basis to facilitate maintenance operation evaluation.

Table 1: Customer Selection Matrix for interview sessions

Market/Users	Managers	Auditors / QA Representative
Surveillance	2	4
Internal Audit	1	-
Technical Audit	1	1
AD	1	3

The team made notes on various observations that were made onsite and utilized this information in the brainstorming sessions to identify the problematic areas in the existing system. The team used questionnaires in a web survey subsequent to the interviews, focus groups and observation sessions to validate the identified process measures with FedEx, its aviation industry partner on the project, and other partnering airlines.

Survey Design for Validation of Process Measures: The users who participated in the online survey (See Figure 1 for a screenshot) consisted of the same user types that were selected for interview sessions. Six subjects, including the manager, for each work function and hence, a total of 24 subjects from FedEx were selected for the first survey to validate the appropriateness of the process measures. The second phase of the survey was conducted with partnering airlines. Twenty subjects from other partnering airlines were asked to take a survey to further validate the research team's findings on the process measures.

Figure 1: Survey Screenshot–Questions' screen

The survey was designed to last a maximum of 60 minutes for each of the four modules: surveillance, internal audits, technical audits, and airworthiness directives. The questions were of two kinds. There were forced-response, and open-ended questions. The team wanted detailed feedback from the subjects taking the survey and hence incorporated a 'comments' field for each question. Every web page of the survey consisted of a link to the process measures definitions document so that they could use it for reference while answering the survey questions. The survey was developed

using HTML, PERL scripting, and the usage of the cgi-bin on the Clemson engineering systems network. The survey responses were stored in text files (.txt) with the date and time stamp in the cgi-bin. The input from this survey was used to refine the identified process measures. The results from the second stage of this survey were fragmented. Very few respondents from other airlines participated in the survey. Consequently, the team proceeded with the data obtained from the FedEx personnel.

RESULTS AND DISCUSSION – PHASE I

Process Measures Identification and Validation

The process measures identified for different maintenance processes are given in Table 2 below. The definitions of these process measures are elaborated in the WebSAT Process Measures Definitions Document available with the team.

Table 2: List of Identified Process Measures (PM)

PM	Surveillance	Technical Audits	Internal Audits	AD
1	In-Process	Compliance/Documentation	Administration	Information Verification
2	Verification	Inspection	Training	Loading and Tracking
3	Final Walk around	Facility Control	Records	
4	Documentation Surveillance	Training & Personnel	Safety	
5	Facility Surveillance	Procedures	Manuals	
6	Procedures Manual Surveillance	Data Control	Procedures	
7		Safety		

The results from the first survey show that these process measures adequately evaluate the respective work functions. In surveillance, four of the six responses (66.7%) indicated that these process measures were sufficient to evaluate the surveillance process. However, two responses suggested that metrics in the "additional findings" module – "information" and "aircraft walk around" should be incorporated as process measures rather than as other modules. For internal audits, two responses of the six (33.3%) indicated that the process measures for this category do not capture data from the FAA's Air Transport Oversight System (ATOS) and hence do not entirely capture the data relevant to the internal audits department. The results obtained for the technical audits indicate that these process measures capture all the relevant data from the technical audit department and also communicate the purpose of each measure appropriately. The responses for airworthiness directives indicate that most of the processes that take place in the AD control group are verification processes and hence the identified process measures capture the data relevant to ADs.

The data collected from the surveillance work domain indicated that there are currently ambiguities in associating a process measure with a particular work card (data point). The QA representatives were required to memorize the definitions of 17 process measures and classify a work card based on the definition of the process measure.

Though the definitions of the existing process measures appear to be unambiguous to the managers they were often confusing to the QA representatives. The research team tried to eliminate the ambiguity by reducing the number of process measures to six and incorporating sub-categories in some of these process measures. The intent was to allow the representative to choose the process measure under which to classify a data point without having to memorize the definitions of the process measures. Two other modules “Additional Findings” and “Fuel Surveillance” that collect data on the surveillance activities were identified by the team to record the data for informational purposes. The team has not considered these two modules as process measures because the surveillance personnel, during the interview sessions indicated that this data is not used to rate vendor performance of maintenance tasks.

The technical audits group had developed several checklists to evaluate various types of vendors. The questions in these checklists were process specific and were grouped into categories based on the requirements they address. The research team formed process measures based on the checklist categories and on Coordinating Agency for Supplier Evaluation (C.A.S.E.) standards. The identified process measures evaluate the standards and procedures of suppliers, fuel vendors, and ramp operations at a system level and ensure compliance with Federal Aviation Regulations (FAR), and established company policies and procedures. All six survey respondents indicated that there are no ambiguities in the identified process measures. The team gathered various checklists used by the internal audits department and have identified that the existing process categorizes the data collected from these checklists based on six process measures. The team reached a consensus that the existing six process measures adequately capture the relevant data to measure the process in the internal audits department. The team did not take into consideration measures drawn from the ATOS system because of project scoping issues. The responses from the AD department indicate that the process measures capture all the relevant data pertinent to AD control process and hence adequately evaluate the process. The identified process measures would eventually enable a standardized data collection through WebSAT across the aviation industry. Furthermore, FAA could disseminate the research findings and implement these process measures across the aviation industry to facilitate standardization within and across airline facilities.

METHODOLOGY – PHASE II

Development of Technical Audits Module

The team then started to design WebSAT’s Technical Audits module. The user-centered design process is practiced through the application of a variety of methodologies within a structured design process. Such methodologies include contextual design (Beyer and Holtzblatt, 1998), task analysis (Gramopadhye and Thaker, 1998; Hackos and Redish, 1998), the development and use of personas (Cooper and Reimann, 2003) and scenarios (Rosson and Carroll, 2002), usability inspection methods (Nielsen, 1993), and usability testing

(Dumas and Redish, 1993; Rubin, 1994). These practices integrated into a design and development methodology as proposed by Ulrich and Eppinger, is structured in four stages:

1. Identifying Needs
2. Product Specifications
3. Concept Generation & Concept Selection
4. Iterative Prototype Testing (low fidelity prototypes)

The following sections will explain how the above mentioned phases were adopted for the development of the Technical Audit (TA) module of WebSAT prototype.

Stage I - Identifying Needs: The research team used interviews, focus groups, observation sessions and surveys as their modes of collecting data on the aviation maintenance processes at FedEx. Three members of the WebSAT research team prepared interview questions before hand. However, these questions were only to guide them through the interview process, and were helpful to tap the various aspects that need to be learnt about the systems at FedEx. The techniques of contextual inquiry proposed by Beyer and Holtzblatt (1998) were used as the interview progressed. If the interviewee shared any information which is not directly related to the question asked but very relevant to the product, the research team was quick enough to emphasize on those topics. Substantial documentation was sought by the team to understand the process better. Observation sessions helped the research team to understand a typical day of the technical auditor. Focus groups conducted with the manager of technical audits and another technical auditor helped the research team identify the various intricacies of the technical audit process. When one person in the team was focused on questioning the users, the other person was more focused on taking down detailed notes. The third person concentrated more in capturing behavioral gestures, concerns and emotions of the user while describing the current system. The team members also switched their roles and if one of them felt appropriate to interrupt the process to clarify certain issue, he / she did not hesitate to do so.

Information Gathered on Technical Audit Process

There are two types of technical audits: 1) Supplier Audits and 2) Fuel, Maintenance and Ramp (FMR) Audits. Further, in supplier audits alone there are several types of vendors involved. For each type of a vendor the auditors could use just one checklist or more than one. The checklists have questions that evaluate the procedures, regulatory policies, compliance standards of the vendors with the requirements of FedEx and FAA. The data collected from the checklists is in the form of Yes, No, Not Applicable, Not-Observed or some open ended comments. The findings obtained are shared with the vendor and the vendor is expected to address the corrective actions in a stipulated period of time. The data collected from the technical audit checklists for a particular vendor is reported to the TA manager by the auditors. This report also contains some of the concerns that the auditor and his comments which could be with respect to the vendor personnel or the facility or fleet type or some other aspect. The only two types of users involved in this work domain are the technical auditor and the TA manager. Having gathered substantial amount of data on the TA work domain, the team

moved towards identifying process measures for the work function. Process measures include all the data collected from the checklists. In order to identify the process measures, the team comprehended the various checklists that existed for TA. The team also studied Coordinated Agency for Supplier Evaluation (C.A.S.E) standards which has a detailed description of the various categories related to vendor evaluation. Using this documentation the team formulated the process measures based on the sections in the checklists.

Stage II - Product Specifications: With the gathered material on the work flows, the team had brain storming sessions where they discussed the transcribed material and encapsulated the information in the form of work flow diagrams. The team converted every customer statement into need statement. These need statements were grouped based on proximity and were then arranged in a hierarchy. Each group was given a name which is the primary need and all the need statements within that group were termed as secondary needs. Similarly every primary need comprised of several secondary needs in them. This list of hierarchy was sent to the client to get an importance rating for each need. The team members also gave a rating to the needs based on their intuition. The average of the rating obtained from the team members was compared with the rating obtained from the client and in many cases it was relatively the same except for very few cases. Based on the project scope and team consensus two needs were eliminated. Every need statement was then converted into a 'metric' which appropriately measures the performance of the product with respect to the need. An example of a customer statement, need statement and its metric is shown in Table 3. Having generated the metrics, the team started the phase of concept generation, while working on competitive benchmarking in tandem. Each member in the team generated one concept. Subsequent to the generation of the concept, the team followed the gallery technique using the whiteboard where the concept was enhanced with various ideas of the team members. The screen shots of the three concepts are shown in the figures below. Different scenarios were developed with respect to the two types of users. Then the team had brainstorming sessions on the pros and cons of each concept and consequently, attempted to enhance each concept to the best.

Table 3: Conversion of Customer Statement to Need Statement and to Metric

Customer Statement	I would like the tool to provide documentation of corrective actions for Non-Systematic audits.
Need Statement	The tool stores documentation on non-systematic audits.
Metric	Time taken to download the documentation on corrective actions for audits
Unit	Seconds

Stage III - Testing: In the next phase of testing, these concepts were pilot tested with two Human-Computer Interaction experts and one Management and Information Systems expert from Clemson University. The testing took place with low-fidelity prototypes, in that the prototypes showed all the features that the concept consists of, albeit, not functional. Prior to testing, they were informed about the

auditor's job role and responsibilities. Subsequently, they were presented with three scenarios and were asked to point out how they would go about performing the task.



Figure 2: Concept 1 - Based on Google Search Engine but with multiple search criteria.

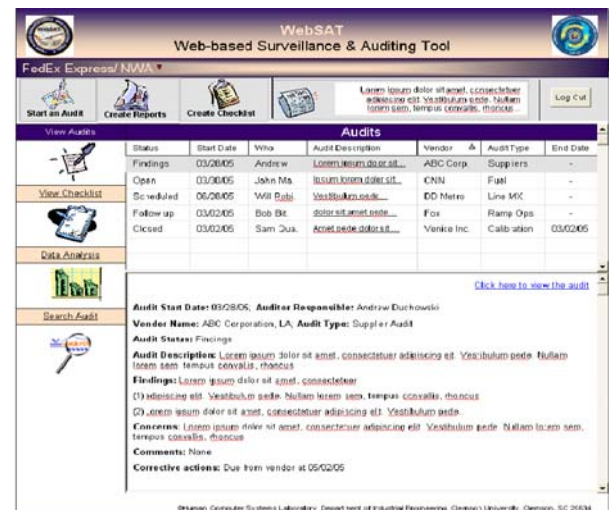


Figure 3: Concept 2 - Based on Microsoft Outlook



Figure 4: Concept 3 - Based on Tab Metaphor

They were also requested to think aloud while performing the task. The feedback obtained from this testing was only documented but was not implemented before the second phase of testing which involved testing with real users. Two audit managers were recruited for testing. They signed a consent form before participating in the study. The users were physically located in Memphis while the experimenters were at Clemson.

To enable smooth testing, the experimenters were sent a PowerPoint file which consisted of the storyboard of all the screen shots with instructions. The scenario was presented to them in one slide and in the next slide the screens appeared. The testing was done on a conference call and hence the team could ensure that the users were on the same page as the experimenters.

RESULTS AND DISCUSSION – PHASE II

Testing of Technical Audits Module

The results from initial testing phase with the faculty members showed that the organization structure of concept three was preferred to rest of the two concepts. The users also mentioned that the grid feature of concept two was very much liked by them and is quite intuitive. The results from final testing also showed that concept three was preferred the best. The grid feature of concept two was preferred by all the users who participated in the two phases of testing. One user mentioned that the dropdown for vendor list needed to be constrained based on other criteria such as vendor type as there could be 600 vendors in total resulting in a lengthy list. With the feedback obtained from testing the concepts were further refined and combined. The screen shot of the final concept is shown in Figure 5. Having selected this concept the team developed this concept using ASP.NET 2002 and SQL server. The organization scheme of this module will be extended to other modules as well.



Figure 5: Final Concept - Tab metaphor of concept 3 combined with data grid of concept 2.

RECENT ACCOMPLISHMENTS

The recent accomplishments of the WebSAT research team are listed below:

- Demonstrated the functionality of the Technical Audits Module to the FedEx group using various auditor scenarios.
- Conducted interview sessions with FedEx personnel to understand the data analysis requirements of WebSAT.
- Research in progress in the areas of
 1. Persona development to enhance the user experience with WebSAT interface -
 - a. Conducted a user profile survey to establish various user categories and generate personas for WebSAT development.
 2. Development of data reduction techniques to interpret qualitative responses in a standardized fashion.
 3. Generation of risk model to provide analysis of substantial maintenance data

Dissemination: Published and presented papers in the following journals and conferences respectively.

1. International Symposium of Aviation Psychology, Oklahoma City in April '05.
2. Industrial Engineering Research Conference, Atlanta, May '05
3. International Journal of Applied Aviation Studies, '05
4. Proceedings of Safety across High-Consequence Industries, St. Louis, September '05.

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